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Local thermal properties of the crust and thermochronometric data - how much can we bias the calculated denudation amount?

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Low temperature thermochronometers are mainly used to decipher crustal denudation histories. However, these methods provide cooling paths that can be confidently translated into denudation rates only if the geothermal gradient at the time of cooling is known. As past geothermal gradients cannot be directly measured, they can be sometimes estimated from the thermochronometric data, when borehole data or vertical profiles are available. In all the other cases, our knowledge of the spatial and temporal variation of the geothermal gradient is limited. It is common practice in many thermochronometric studies to calculate the amounts and rates of denudation through time assuming a constant, average present-day value for the geothermal gradient. In this study, using 1D and 3D (Pecube) models, we have investigated the impact of crustal heat production and thermal conductivity (κ) on the estimated values of denudation, taking central west Britain as our case study. In this region, the apatite fission track (AFT) ages describe a characteristic U-shape pattern with early Cenozoic ages in the English Lake District and older, up to 200 Ma ages northwards in S Scotland, and southwards in N Wales. This pattern, which could be referred to a difficult to justify localized, differential denudation, can actually be best explained as an effect of the spatially variable heat production. The insulating effect of low thermal conductivity Upper Mesozoic sedimentary rocks, composed largely by chalk, increases the palaeogeothermal gradient and reduces the amounts of denudation, especially in the Lake District, where a heat productive granite batholith increases the local heat flow. The observed AFT age pattern may be, therefore, explained without any significant variation of early Cenozoic denudation across central west Britain. If the thermal proprieties of the crust are not taken into account, denudation in the Lake District will be overestimated by a factor of 1.5-2.0 and the mechanisms driving such localized differential denudation unexplained. Thermochronometric analyses are often made on high heat producing intrusive rocks that have been exhumed via erosion of the overlying low thermal conductivity sedimentary blanket. Our models indicate that an increase of heat production value by 1 μW/m^3 within $\sim$10 km thick batholith induces a gradient increase of $\sim$3.2°C/km. A thermal conductivity decrease generates an exponential increase of the geothermal gradient within a given layer; for instance, for low conductive rocks, such as chalk ($\kappa \approx 1.5$ W/mK), geothermal gradients can reach up to 40°C/km for an average heat flow values ($\sim$60 mW/m^2) and exceed 60°C/km if the underlying body has heat production of 4 μW/m^3. The models point to the importance of carefully considering the nature of the material removed, as low conductive sediments, especially when covering heat productive basement, may produce abnormally high values of geothermal gradients, causing drastic changes in cooling rates. If these are translated in denudations rates using a 'normal' geothermal gradient, as it is often done, amounts of denudation will be significantly overestimated, like in the case of the Lake District.